

RISK FACTORS AND TRENDS IN NEONATAL MORTALITY IN A SPECIAL CARE NEWBORN UNIT IN A TERTIARY CARE HOSPITAL IN BANGLADESH

By

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Abstract

Background: Bangladesh's neonatal mortality rate in 2017 was 18.4 deaths per 1000 livebirths. Special care newborn units (SCANUs) have been established in hospitals country-wide to improve neonatal survival.

Methods: We conducted a retrospective cohort study in the SCANU of Faridpur Medical College Hospital, Bangladesh to describe the neonates admitted to the unit in 2018, describe trends in admissions and deaths, and investigate risk factors associated with death within 48 hours of admission to the unit. Data were extracted from paper medical records at FMCH and digitized. Neonates who were admitted alive to the unit between January and November 2018 with admission dates available in the medical records were described based on their demographic and clinical characteristics. Logistic regression models were used to examine the relationship between death within 48 hours of admission to the unit and potential demographic and clinical risk factors.

Results: The study population consisted of 693 neonates; 38% (n=263) died in hospital, 24% (166/693) within 48 hours of admission and 49% (n=340) left the unit against medical advice. Sixty percent were admitted on the day of birth, 56% were male, and 82% were born prematurely (before the completion of 37 weeks of pregnancy). There appeared to be an increase in admissions in the latter half of the year. Each additional day of age was found to be associated with a 5% reduction in the odds of death within 48 hours of admission to the unit (OR: 0.95, 95% CI: 0.9, 0.99); male sex (OR: 1.5, 95% CI: 1.04, 2.2), prematurity (OR: 2.5, 95% CI: 1.3, 4.7) and a perinatal asphyxia diagnosis (OR: 2.2, 95% CI: 1.4, 3.4) were all associated with an increased odds.

Conclusion: The high mortality among neonates in this unit, and the identification of risk factors associated with death within 48 hours of admission, warrants further investigation to identify strategies to improve neonatal outcomes as well as potential risk factors amongst maternal characteristics. Other SCANUs in the country with similar treatment gaps may also require attention and resources in order to improve child survival in these units.

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Introduction

The neonatal period is considered the most vulnerable period in a child's life, with the risk of dying being the highest in the first month of life (UN Inter-agency Group for Child Mortality Estimation, 2018). Although a steady decline has been observed in neonatal mortality globally, this decline has been much slower than the global decline observed in mortality amongst older children from 1990 to 2017; the decline in neonatal mortality was approximately 51% in comparison to a 63% decline in mortality in children aged 1-4 years (UN Inter-agency Group for Child Mortality Estimation, 2018). This trend has resulted in neonatal deaths accounting for an increasingly larger proportion of global under-5 deaths in comparison to other deaths classified as under-5 (United Nations, 2013), approximately 47% in 2017 (UNICEF Data, 2018).

Although neonatal mortality remains a global problem, the burden of neonatal deaths is primarily focused in sub-Saharan Africa and South Asia (UNICEF Data, 2018). While neonatal deaths accounted for a relatively lower proportion of deaths amongst children under-5 (37%) in sub-Saharan Africa in 2017 in comparison to South Asia, neonatal deaths in South Asia accounted for approximately 60% of under-5 deaths in the region in 2017 (UN Inter-agency Group for Child Mortality Estimation, 2018 & UNICEF Data, 2018). South Asia's neonatal mortality rate in 2017 was 27 deaths per 1,000 live births – comparable with the neonatal mortality rate in sub-Saharan Africa (27.2 deaths per 1,000 live births) and much higher than the neonatal mortality rates in developed regions such as North America (4 deaths per 1,000 live births) and Europe (3 deaths per 1,000 live births) (UN Inter-agency Group for Child Mortality Estimation, 2018). Of the 2.5 million neonates who died in their first month of life in 2017

worldwide, South Asia accounted for 38% of the deaths, with 973,000 neonatal deaths in the region that year (UN Inter-agency Group for Child Mortality Estimation, 2018).

Achieving global child mortality reduction goals has been difficult in this region. Sustainable Development Goal #3 calls for all countries to reduce their neonatal mortality rates to 12 deaths per 1,000 live births by 2030 (United Nations, 2018). Prior to the implementation of the SDGs in 2015, Millennium Development Goal #4 called for a reduction of two-thirds in mortality in children under the age of five from 1990 till 2015 (United Nations, 2015) – although South Asia saw a substantial decline in neonatal mortality over the 25 years, (United Nations Development Programme, 2015) most countries in the region did not achieve the global target (Asian Development Bank, 2015).

Bangladesh was one of three South Asian countries to achieve MDG 4 (Asian Development Bank, 2015). Bordered by India and Myanmar, Bangladesh's population was approximately 159 million people as of July 2018, making it the 8th most populous country in the world at the time (Central Intelligence Agency, 2019). The GDP in 2017 was estimated at approximately \$261.5 billion. Twenty four percent of the population was considered to be below the poverty line in 2016 (Central Intelligence Agency, 2019). Although factors such as entrenched poverty and poor access to high-quality health services have hampered Bangladesh's progress towards achieving universal health care by 2032 (International Development Research Centre, 2018), initiatives such as immunization campaigns, Vitamin A supplementation and successful control of diarrheal diseases aided in Bangladesh meeting MDG 4's requirements and drastically improving the health of women and children in the country (International Development Research Centre, 2018 & United Nations Development Programme, Bangladesh).

While improving neonatal survival was not an explicitly separate objective under the MDGs like it is under the SDGs, Bangladesh's commitment to improving newborn health in particular is bolstered by the implementation of Special Care Newborn Units, commonly called SCANUs. SCANUs were established to avert neonatal deaths due to preventable causes such as infection and other birth complications, as part of a UNICEF newborn health initiative which also included the provision of skilled healthcare workers and clean facilities (UNICEF Bangladesh). The main services provided by SCANUs include care and management of sick neonates, barring those who require surgical intervention and mechanical ventilation, as well as follow-up for those deemed to be at high risk of adverse outcomes. The units also provide referral services and employ medical professionals trained in newborn care (Directorate General of Health Services, 2011). UNICEF set up SCANUs in four medical college hospitals (UNICEF Bangladesh), while USAID and Save the Children have also installed SCANUs in the districts of Jaintapur (U.S. Agency for International Development, 2019) and Lakshmipur (Save the Children, Bangladesh, 2016) respectively. As of 2017, SCANUs have been established in 42 facilities in Bangladesh (Directorate General of Health Services, 2017). Despite the implementation of the SCANUs, neonatal mortality is still a matter of concern in Bangladesh - as of 2017, the neonatal mortality rate was 18.4 deaths per 1,000 live births (UNICEF Data, 2018), considerably higher than the 2030 target.

Common risk factors for neonatal mortality worldwide include birth complications associated with prematurity, as well as intrapartum-related complications, and diagnoses of sepsis, meningitis, pneumonia and other congenital defects (Liu, L. et al, 2012). The state of affairs is no different in South Asia – in 2017, prematurity and intrapartum complications were determined to be the main causes of neonatal death in South Asia (UNICEF Data, 2018). Prior

studies have also established diagnoses of prematurity, birth asphyxia, neonatal sepsis, and pneumonia as leading risk factors for neonatal mortality in Bangladesh (Khatun, F. et al, 2012 & Chowdhury, H. R. et al, 2010). Maternal characteristics and socio-economic factors such as low maternal age, low maternal education, lack of sanitation, birth rank, and lack of antenatal care-seeking have also been indicated to be risk factors for neonatal mortality in the country (Kamal, S. M. M., 2015 & Kamal, S. M. M. et al, 2012 & Roy, S. et al, 2018). While risk factors for community-based neonatal cohorts have been extensively studied in Bangladesh with the help of community health workers (Shah, R. et al, 2014 & Mitra, D. K., et al, 2018), risk factor profiles in hospital settings such as the SCANUs are fewer. Previous research has shown that receiving care at a district hospital or medical college in Bangladesh does not necessarily reduce the risk of neonatal death (Halim A. et al, 2016), which indicates a need to understand what factors hamper the effectiveness of hospital care in averting adverse outcomes in neonates. Evaluations of case fatality rates associated with the services provided in SCANUs in India identified an association between aseptic practices and positive neonatal outcomes in these units based on variation of the case fatality rates associated with aseptic practice scores (Neogi S. B. et al, 2011); the same has not been established for SCANUs in Bangladesh. Considering that SCANUs in Bangladesh have been established in multiple districts across the country with the goal to improve neonatal survival through the provision of life-saving treatments, characterizing their functioning can allow for unique insight into the units studied and their impact on neonatal survival. Identifying clinical risk factors for neonatal mortality in different facilities with SCANUs or similar units is crucial if progress towards reducing neonatal deaths is to be made and has the potential for the implementation of targeted interventions to address these factors. Seasonality in neonatal deaths in Bangladesh has been previously established, with the occurrence of neonatal deaths increasing

in the winter (Becker, S., Weng, S., 1998); studying possible trends in seasonal clustering in the admissions and deaths in the unit may highlight factors that affect neonatal survival and the individual newborn periods throughout the course of the year.

This study aims to profile a SCANU in Faridpur Medical College Hospital in the district of Faridpur, Dhaka, Bangladesh. We aim to describe the individuals admitted to the SCANU, as well as any underlying seasonal patterns observed in the admissions and deaths in the unit in 2018. Additionally, we aim to preliminarily characterize potential risk factors associated with early death post hospital admission i.e. death occurring within the first two days of admission to the unit.

Methods

Study Design and Site

The study team conducted a retrospective longitudinal study of neonates who were admitted to the Special Care Neonatal Unit (SCANU) at Faridpur Medical College Hospital (FMCH) between 1st January 2018 and 30th November 2018. FMCH is a tertiary-level healthcare facility in the district of Faridpur that serves as a referral hospital and has had an active SCANU since 2009, which served as the primary study site for this study.

The SCANU primarily admits premature, low birthweight neonates considered at risk for perinatal septicemia, asphyxia, neonatal jaundice, respiratory infections, and other birth complications.

Data Extraction and Digitization

Hospital officials at FMCH extracted data from the paper medical records of all neonates admitted to the unit in 2018. A data extraction instrument consisting of 120 variables was used to extract and digitize the relevant data. A trained physician on the study team entered data from the records including important dates for each neonate such as the date of admission to the ward, the date of death or discharge, whichever came first, and the date of birth. Information on potential risk factors including the age at admission in days, sex at birth, admitting and subsequent diagnoses, location of the birth, delivery method, antibiotic regimen, treatments administered such as intubation, oxygen masks, ventilation, and thermal regulation, pathogens detected, sharing of an incubator, and geographic proximity to a neighboring incubator were also entered.

Analysis Methods

For the descriptive objectives of this study, we considered neonates eligible for the study if they were between the ages of 0 and 28 days at admission to the unit, were admitted alive to the SCANU between January and November 2018, and had available medical records detailing the SCANU admission dates and outcomes. We considered the dates of admission to the SCANU as the time origin in the study for each eligible neonate, and the date of hospital discharge or death, whichever came first, as the end of observation time. Therefore, the duration of time spent as a patient in the SCANU was defined using the date of admission and the date of death or discharge, whichever of the latter came first. Individuals admitted between 1 to 23 hours were considered to be admitted for one day. Neonates with missing discharge and death dates were assumed to have absconded after being admitted to the SCANU for one day, since it was definitively known that they were admitted to the unit for at least one day. No information on antibiotics or treatments administered was recorded for these individuals, which indicates they may not have been admitted to the unit for a substantial amount of time.

We calculated proportions for demographics and other measured characteristics to compare the neonates that died while admitted to the unit to those that were discharged from the unit and those that left the unit against medical advice. Differences in characteristics between the groups were evaluated using χ^2 test statistics and the Kruskal-Wallis H test.

We calculated the proportion of neonates that died in the entire study population using the total number of deaths in the study population as the numerator and the eligible study population size as per the inclusion criteria, as the denominator.

We also calculated cause-specific case fatality proportions using the number of deaths in those diagnosed with prematurity, low birthweight, sepsis, perinatal asphyxia, hypoxic-ischemic

encephalopathy and respiratory distress throughout the duration of the study. The denominator was considered to be the number of neonates eligible for this analysis as per the inclusion criteria stated. Individuals identified as premature or having low birthweight were assumed to have been categorized as per the World Health Organization's definitions: birth before the completion of 37 weeks of pregnancy was considered premature, and a birthweight below 2500 grams was considered to be low (Zupan, J., & Åhman, E.,2006).

To analyze the occurrence of the deaths with respect to time spent admitted to the ward, we set up a survival dataset and plotted a Kaplan-Meier curve to look at survival of the neonates over time, in the eligible study population. The date of admission to the unit was designated as the time of study entry, and the dates of death or discharge, depending on whichever date came first, were designated as the time of study exit. The number of days spent as a patient in the unit was considered as the time axis. In-ward death was specified as the event of interest, and individuals who were discharged were considered censored. Neonates with no exit dates were considered censored after one day of admission to the unit.

Using the dates of admission and the outcomes determined for each individual neonate, we displayed potential seasonal trends in SCANU admissions and deaths from January till the end of November in 2018.

For the second objective, we defined the outcome of the analysis as in-ward neonatal death within the first 48 hours of admission to the SCANU between January and November in 2018, modeled as a binary variable. Preliminary data exploration indicated a large proportion of deaths occurring within the first two days of admission - in order to characterize risk factors associated with death soon after admission to the unit, we chose a cut-point of 48 hours. The conceptual framework behind the analysis is described ([Figure 1](#)). For the purpose of this

analysis, individuals who left against medical advice within 48 hours of admission were excluded in addition to the individuals already excluded for the descriptive objectives. We calculated proportions for demographics and other measured characteristics to compare the neonates that died in the first 48 hours of admission to those that survived beyond 48 hours from admission. Differences in characteristics between the groups were evaluated using χ^2 test statistics and the Wilcoxon-Mann-Whitney test.

To assess for potential risk factors associated with death within 48 hours of admission to the unit, we used univariable and multivariable logistic regression models. The univariable models were used to characterize possible associations between individual covariates such as age at admission, sex, prematurity (defined as birth before the completion of 37 weeks of pregnancy), low birthweight, diagnoses of sepsis, perinatal asphyxia, hypoxic-ischemic encephalopathy or respiratory distress, home as a birth location, delivery methods, and incubator sharing logistics and the outcome. We included covariates in the multivariable model based on the biological rationale associated with risk factors previously established for neonatal mortality as well as a $p < 0.1$ specified a priori, for flexibility in the inclusion criterion for the adjusted model. Mickey and Greenland have previously found that $p < 0.05$ failed to identify important covariates when screening them for inclusion in a multivariable model and concluded that significance levels for p-values can be increased in order to decrease type II error when selecting covariates (Mickey R. M., Greenland S., 1989). We subsequently ran the multivariable logistic regression model to assess the effects of the chosen covariates such as age at admission, sex, and diagnoses for prematurity, perinatal asphyxia and hypoxic-ischemic encephalopathy, to analyze their potential associations with the risk for the outcome. Age was modeled as a continuous variable, while sex and the diagnoses were modeled as binary variables. We reported the crude

and adjusted odds ratios with their 95% CIs as a measure of the strength of the associations, to determine if the covariates functioned as risk factors for early death after admission to the ward.

Ethics Statement

Prior to analysis, data were de-identified via the removal of personally identifiable information such as names and addresses. The study protocol was reviewed and approved by the Research and Ethical Review Committees of the International Centre for Diarrheal Disease Research, Bangladesh.

Results

Description of the Study Population

For the descriptive objectives of this study, of the 702 neonates admitted to the unit in 2018, 693 neonates were considered eligible for inclusion in the study population. We excluded 9 individuals due to their admission to the unit after 30th November 2018 (1.3%). The median duration of time spent in the unit for the 693 neonates was 3 days, with an interquartile range of 3 days. The mean duration of time spent in the unit was 4 days, with 1 day being the minimum amount of time spent in the unit and 22 days being the maximum.

Over the 11-month period, in the population of 693 neonates, the proportion of neonates that died in the unit was 38% (263 neonates). In the same time period, 49% (340 neonates) absconded or were discharged against medical advice and 13% (90 neonates) were discharged. A similar trend was observed in each month of admission, with discharge from the unit being the least likely outcome across the 11-month period. (see Supplementary Figure 1).

Comparisons between the neonates on the basis of their outcomes of death, discharge and leaving against medical advice indicated that the median age of admission was less than 1 day for those that died and those that left against medical advice. However, for those that were discharged, the median age of admission was 1 day ($p<0.001$). Male neonates outnumbered female neonates in those that died (60% male) and those that left against medical advice (56% male). Individuals who died were more likely to receive diagnoses of prematurity (91%, 239 neonates), low birthweight (93%, 244 neonates), perinatal asphyxia (39%, 102 neonates) and respiratory distress syndrome (9%, 23 neonates), in comparison to the other two outcome groups ($p<0.001$), indicating a statistically significant difference in survival between the outcome groups. However, individuals who were discharged had the largest proportion of those diagnosed

with sepsis (n=15, 17%) ($p<0.001$). Although the diagnosis of prematurity was based on the occurrence of the birth before 37 weeks of pregnancy were completed, gestational age was not routinely recorded in the medical files, leading to a lack of specificity within the diagnoses of prematurity due to the unavailability of data. All three outcome groups indicated that more than half of the births took place at locations that were not the home of the family. Of those who died, 61% (160 neonates) had been born through a normal vaginal delivery, in comparison to the 42% (38 neonates) of those who were discharged and the 54% (182 neonates) of those who left against medical advice who were born through the same method ($p<0.001$). Incubator-sharing was not prevalent in the three groups, with 90% or more of the neonates in each group being assigned their own individual incubator ([Table 1](#)).

The distribution of diagnoses across those that died, those who were discharged and those who left against medical advice was also described ([Figure 2](#)). Those diagnosed with respiratory distress had the largest proportion of deaths (66%, 23/35 neonates) of all the diagnoses, while the collective proportion of those diagnosed with conditions other than prematurity, low birthweight, sepsis, perinatal asphyxia, hypoxic-ischemic encephalopathy, and respiratory distress was 30% (21/70 neonates). Individuals diagnosed with sepsis had the largest proportion of individuals who recovered and were discharged (31%, 15/49 neonates), while individuals diagnosed with respiratory distress had the smallest proportion of individuals discharged (3%, 1/35 neonates). Proportions of those who left the unit against medical advice ranged from 31% to 48% across all the diagnoses, barring those whose diagnoses were unknown. The outcomes of these individuals remain uncertain, due to a lack of data regarding their decision to leave the unit as well and their outcomes after exiting the unit.

The Kaplan-Meier curve indicated a consistent decline in the probability of survival in the first week of admission to the unit, with a drop in the probability of survival in the first two days followed by a more staggered decline. The median survival time is approximately 8 days from admission to the unit ([Figure 3](#)).

Trends in Admissions and Death in the Unit in 2018

Based on the trend analyses conducted, January had the highest proportion of deaths (53%, 27/51 neonates admitted that month), while September had the lowest proportion of deaths (24%, 19/81 neonates admitted that month). The proportion of those dead varies from 31% to 53% of those admitted in the respective months, over the 11-month period. Barring January, the proportion of those dead is less than 50% of the admitted in the remaining months. The number of admissions ranged from 39 (February) to 58 (March) neonates in the first half of the year (up till June). However, from July onwards, admissions appear to increase in comparison to the first half of the year, with the number of admissions ranging from 55 (June) to 101 (October) neonates till November ([Figure 4](#)).

Risk Factor Identification for Death within 48 Hours of Admission

For the second objective, where we aimed to identify risk factors for death within 48 hours of admission to the unit, we determined 646 neonates to be eligible for inclusion in the study population for this analysis, after excluding 47 individuals who absconded within 48 hours of admission to the unit. A quarter of the neonates (26%, 166 neonates) considered in this study population died within 48 hours of admission to the unit. Of those that died within the first 48 hours, 88% were considered premature, compared to the 79% premature amongst those who

survived beyond the first 48 hours; the difference in survival between these two groups was statistically significant. ($p=0.03$) The difference in survival beyond the first 48 hours was also statistically significant amongst those with a diagnosis of perinatal asphyxia and those without - nearly half of those who died within the first 48 hours were diagnosed with perinatal asphyxia (46%), while only 29% of those that survived beyond the first 48 hours had the same diagnosis. ($p<0.001$) ([Table 2](#)).

Finally, we presented crude and adjusted odds ratios for death within 48 hours of admission to the unit to identify potential risk factors amongst demographic and clinical characteristics of the patients ([Table 3](#)). The crude results from the univariable models indicated that each additional day of age at admission (OR: 0.93, 95% CI: 0.88, 0.98) was associated with a reduction in the odds of death within 48 hours of admission to the unit, while male sex (OR: 1.5, 95% CI: 1.1, 2.2), prematurity defined as birth before the completion of 37 weeks of pregnancy (OR: 2.2, 95% CI: 1.2, 4.2), and a diagnosis of perinatal asphyxia (OR: 2.1, 95% CI: 1.5, 3.0) indicated a higher odds of dying in the first 48 hours of admission to the unit. Although a diagnosis of hypoxic-ischemic encephalopathy also indicated higher odds for the outcome, the odds ratio estimate was only marginally significant (OR: 1.5, 95% CI: 0.9, 2.5). Adjusting for these variables using a multivariable model indicated that an increase of one day in the age at admission was associated with a 5% decrease in the odds of dying within 48 hours of admission. (OR: 0.95, 95% CI: 0.9, 0.99). Male neonates had 1.5 times the odds of dying within 48 hours, in comparison to female neonates (OR: 1.5, 95% CI: 1.04, 2.23). A diagnosis of prematurity increased the odds of dying in the first 48 hours by 150% (OR: 2.5, 95% CI: 1.3, 4.7), while a diagnosis of perinatal asphyxia increased the odds by 120% (OR: 2.2, 95% CI: 1.4, 3.4).

Discussion

Our analysis of the data revealed a large proportion of neonatal deaths in the unit (38%) through 11 months in 2018. In comparison, the proportion of deaths amongst neonates attended by hospital physicians in the United States is approximately 0.06% (Grünebaum, A. et al, 2017). A study similar to ours was conducted in a neonatal intensive care unit in a tertiary care hospital in India and reported a proportion of neonatal deaths of 46% (Tagare, A. et al, 2013) which indicates that a proportion of deaths this high may not be uncommon in certain geographic regions. Regardless, the high proportion of deaths in the SCANU is alarming, despite the fact that neonates admitted to the unit are already sick and therefore may be less likely to survive.

Comparing the neonates based on their outcomes – whether they died, were discharged, or left the unit against medical advice – indicated that the neonates who died were more similar to those who left against medical advice than to those that were discharged. This is evidenced by the differences in the median age of admission, proportions of those with specific diagnoses as well as the method of birth delivery, where individuals who were discharged were older at admission, healthier and born through caesarean sections in comparison to those in the other two outcome groups. Caesarean sections have been previously shown to be associated with lower odds of neonatal death in Bangladesh (Owais A. et al, 2013). Although we possess no specific information as to the true outcomes of those individuals that left against medical advice, the similarities between this group of neonates and those that died reveals that those who left may be comparable to those who died. Possible reasons for these neonates being discharged against advice may be due to the parents of these neonates choosing to have their children discharged from the unit – either due to an inability to sustain payment of the hospital bills, or a desire to

have their child die at home instead of the hospital. The latter reason would assume that the parents were aware of the full extent of their child's illness and were making a conscious decision while accounting for it.

Individuals who were discharged also presented with the largest proportion of individuals diagnosed with sepsis. Sepsis has been established globally as a risk factor for neonatal mortality (Lawn, J. E. et al, 2005) and has been identified previously as a cause of death amongst neonates in Bangladesh (Khatun, F. et al, 2012). It is possible that we observe better survival outcomes associated with sepsis diagnoses in our study population due to neonates with severe cases of sepsis dying before they can be admitted to the SCANU, thus resulting in them being excluded from the study population for this analysis. This would also explain the lower number of neonates diagnosed with sepsis ($n = 48$), in comparison to other outcomes known to be risk factors for neonatal death such as prematurity and perinatal asphyxia.

Considering the other diagnoses, respiratory distress syndrome, which has the highest proportion of deaths attributed out of all the diagnoses in this study population, commonly occurs in premature neonates due to a lack of anatomical development in the lungs (Hermansen, C. L., & Lorah, K. N., 2007) and has an established association with neonatal mortality in South Asian countries such as Pakistan (Bhutta Z, 1997).

The descriptive survival curve helped determine that deaths in this unit occurred closer to the date of admission to the unit. This indicates that the neonates may have been severely ill on admission, thereby skewing their chances of survival regardless of the setting they are in. Since information on gestational age was not available to us, it is unclear if the neonates being admitted were simply born too early to have a reasonable chance of surviving their hospital stay

and being discharged as healthy neonates. Information on low birthweight was missing as well – although it is known to be only indirectly associated with neonatal death, 60-80% of the neonates that die globally are classified as having low birthweights. (Lawn, J. E. et al, 2005).

The trend analyses indicated differences in the number of new admissions each month, as well as the number that died each month. The increase in the number of admissions in the latter half of the year indicates there may be a seasonality in the number of admissions – it is possible that external drivers influence the occurrence of adverse neonatal outcomes or encourage healthcare-seeking amongst parents in the later months of the year. Additionally, considering that 60% of the neonates (n = 416) overall were admitted to the unit on the day they were born (see Supplementary Table 2), a seasonality in births may also be indicated. More data across multiple years would be required to adequately characterize these hypothesized trends.

Neonates who died within 48 hours of admission to the unit were more likely to be male, premature, and have diagnoses of perinatal asphyxia compared to those neonates that survived beyond the first 48 hours from unit admission. These results were also corroborated by the regression analysis, where lower age at admission, male sex, and diagnoses of prematurity and perinatal asphyxia were identified as potential risk factors for death within the first 48 hours of admission. Similar results are also observed when considering death in the unit as the primary outcome using logistic regression models (see Supplementary Table 1). This aligns with the literature on neonatal mortality in Bangladesh: prematurity is a well-established cause of death in the neonatal period, as is asphyxia and the complications associated with it (Lawn, J. E. et al, 2005). A previous study identified prematurity as one of the main causes of neonatal death in rural Bangladesh, and males accounted for 60% of the neonatal deaths (Owais A. et al, 2013).

Globally, the disparity in survival across gender categories in premature neonates is particularly stark – males have worse survival than females when considering adverse neonatal outcomes such as hemorrhages, and congenital malformations (Naeye R.L. et al, 1971). In addition to male sex being a risk factor for mortality on the basis of perinatal characteristics such as low Apgar scores, male neonates have also been found to be at higher risk for adverse neurological outcomes and disability in comparison to female neonates, should they survive into infancy (Kent, A. L. et al, 2012). This ‘male disadvantage’ indicates that the effect of sex on neonatal outcomes is independent of the biological disease processes involved, and that male sex is an important risk factor for neonatal mortality (Naeye R.L. et al, 1971). Younger age also has an established association with neonatal death - studies from Southeast Asian and sub-Saharan African countries report a high burden of neonatal deaths in the first 3 days after birth (Sankar, M. J. et al, 2016), indicating that younger neonates in these settings are more likely to die than older neonates.

Limitations

One of the main limitations of the study is the lack of specificity in the data available from the medical records. Due to a dearth of information regarding gestational age at birth of the individuals included in the study population, the status of prematurity could not be stratified into the sub-categories of extremely preterm (<28 weeks), moderately preterm (28-32 weeks) and late preterm (32-37 weeks). The sub-categories of prematurity have been previously shown to have different levels of survival at each stage, with the highest population attributable fraction observed in extremely preterm individuals (Baqui, A. H. et al, 2013). Being unable to stratify preterm individuals in our study population into these sub-categories may have obscured certain nuanced effects that would have been reflected otherwise in the stratified estimates. Additionally,

neonatal birthweights were not reported – due to the lack of definition regarding how neonates were classified as having a low birthweight, we were unable to assess its role in this analysis. Since the definitions of prematurity and low birthweight were unclear, the default cutoffs of 37 weeks and 2500g respectively were assumed for the purpose of this study, however this information was not specified in the medical records. There was also missing data on maternal characteristics, such as maternal age, and therefore we could not assess for risk factors amongst these characteristics, although such characteristics have established associations with neonatal mortality (Kamal, S. M. M., 2015).

Another limitation lies in the fact that nearly half of the study population for the descriptive objectives either absconded or was discharged against medical advice (49%). Assumptions of survival for these individuals were not made due to the lack of data available on what may have occurred after these neonates left the unit and the status of their true survival outcomes. Assumptions of death could not be made since the individuals were alive when they left the hospital. This group also includes neonates with missing discharge dates, whom we assumed absconded after one day of admission – since this includes only 19 neonates (2.7%), it is likely that this assumption will not bias estimates based on the outcomes. The descriptive analyses indicated that these individuals were comparable demographically, clinically and diagnostically to those who died, therefore the lack of certainty regarding the true outcomes of those who absconded or left against medical advice possibly indicates that our reported proportion of those who died is an underestimate. The lack of data on their survival outcomes also affects our interpretation of the cause-specific case fatality proportions – it is possible that more deaths may be attributed to specific diagnoses than reported in the descriptive analyses.

A limitation of the regression analysis may be that the comparison groups considered are similar, due to the nature and structure of the outcome. In order to assess for risk factors associated with early death on being admitted to the unit, a 48-hour cut-point was chosen to separate the two groups. Although the group of neonates that died within the first 48 hours of admission to the unit comprised 63% of the deaths that occurred in the study population overall, 36% of those that died by the end of the study did survive the first 48 hours and died in the subsequent days. This indicates that the two groups considered in this case were inherently structured to be similar in one aspect, since both groups contain individuals that died during their time in the unit. This may possibly bias estimates and decrease the strength of the associations characterized for the potential risk factors and the outcome chosen.

Strengths

The strengths lie in the longitudinal nature of the study; we were able to gain an idea of the risk factors associated with death within 48 hours of admission and were able to characterize how long neonates were admitted to the study and whether these durations differed across those with different outcomes. This data may also allow us to look at risk factors associated with early neonatal death (<7 days of age) in the future. Other studies conducted in SCANUs in Bangladesh have mostly used cross-sectional data, or have data collected for less than half a year. This study also succeeds in comprehensively describing the population of neonates admitted to the SCANU at Faridpur Medical College Hospital based on their demographic and clinical characteristics and helps preliminarily understand the unique population that is admitted to this ward.

Conclusions

Of all the neonates admitted to the unit from January through November 2018, 38% (n = 263) died during their time in the unit and 49% (n = 340) left against medical advice, while only 13% (n = 90) were discharged following recovery. Those who left against medical advice appear demographically and clinically more similar to those that died while admitted to the ward than those that were discharged from the unit. Approximately a quarter of the study population died within 48 hours of admission to the unit. Factors found to be associated with death within 48 hours of admission to the unit included younger age at admission to the unit, prematurity, and perinatal asphyxia. These findings emphasize the need for higher treatment capacity in order to address gaps in treating younger, premature neonates diagnosed with perinatal asphyxia, as well as assessing maternal health and identifying potential risk factors associated with neonatal death in the unit.

Recommendations

Based on the high incidence of mortality in the unit, further investigation into the factors associated with it is necessary if conditions in the unit are to be improved in order to support neonatal survival and ensure better health outcomes. Medical records ought to include information regarding the gestational age, as well as any other maternal information available such as maternal infection and age, in order to fully clarify a neonate's risk profile for mortality. Evaluations of the services provided in the SCANU could be conducted, to assess their impact on neonatal survival separately from the clinical characteristics outlined in this study; these could include assessments of the functioning of the incubators, maintenance of aseptic practices in the unit and the effects of incubator sharing on neonatal outcomes. Additionally, it is possible that other SCANUs in Bangladesh are facing the same issues regarding the incidence of mortality – it

is important that these units also get the requisite resources to help them address the specific gaps in treatment that are affecting unit-specific neonatal survival.

Tables and Figures

Table 1: Comparisons between Neonates based on Outcomes (Death, Discharged from Unit, Left Against Medical Advice) and their Demographic, Clinical and Diagnostic Characteristics, Special Care Newborn Unit, Faridpur Medical College Hospital, Bangladesh, 2018

	Neonates that Died N = 263 (38%)	Neonates that were Discharged N = 90 (13%)	Neonates that Left against Medical Advice N = 340 (49%)	P-values
Age at admission in days Median (IQR)	0 (1)	1 (5)	0 (2)	0.002 ^{††}
Sex				
Female individuals	106 (40)	43 (48)	147 (43)	0.2
Male individuals	157 (60)	47 (52)	189 (56)	
Unknown	0 (0)	0 (0)	4 (1)	
Admitting Diagnosis				
Prematurity*	239 (91)	53 (59)	252 (74)	<0.001
Low birthweight[†]	244 (93)	60 (67)	283 (83)	<0.001
Sepsis	16 (6.1)	15 (17)	18 (5.3)	<0.001
Perinatal Asphyxia	102 (39)	24 (27)	99 (29)	<0.001
HIE[‡]	39 (15)	14 (16)	33 (9.7)	0.1
Respiratory Distress Syndrome	23 (9)	1 (1)	11 (3.2)	<0.001
Other	19 (7)	21 (23)	30 (8.8)	<0.001
Unknown	0 (0)	0 (0)	26 (8)	<0.001
Homebirth				
No	151 (57)	60 (67)	193 (57)	0.07
Yes	51 (19)	10 (11)	46 (14)	
Unknown	61 (23)	20 (22)	101 (30)	
Delivery Method				
Normal vaginal delivery	160 (61)	38 (42)	182 (54)	<0.001
Caesarean Section	90 (34)	46 (51)	114 (34)	
Unknown	13 (5)	6 (7)	44 (13)	
Sharing an Incubator				
No	238 (90)	86 (96)	312 (92)	0.3
Yes	25 (10)	4 (4)	28 (8)	

*Prematurity, defined as birth before the completion of 37 weeks of pregnancy.

[†]Low birthweight, defined as a birthweight less than 2500g.

[‡]HIE, Hypoxic-Ischemic Encephalopathy

[#]P-value calculated using the Kruskal-Wallis H test.

P-values were estimated using Kruskal-Wallis H tests for medians and χ^2 test statistics for differences in proportions. Pearson's chi square test was the default test conducted.

Table 2: Demographic, Diagnostic and Clinical Characteristics of the Study Population for the Regression Analysis, Special Care Newborn Unit, Faridpur Medical College Hospital, Bangladesh, 2018

	Neonates that Died in the first 48 Hours of Admission N = 166 (26%)	Neonates that Survived Beyond the first 48 Hours of Admission N = 480 (74%)	P- values
Age at admission in days Median (IQR)	0 (1)	0 (3)	<0.001 ^{ss}
Sex			
Female individuals	61 (36.8)	224 (46.7)	0.07
Male individuals	105 (63.3)	255 (53.1)	
Unknown	0	1 (0.2)	
Admitting Diagnosis			
Prematurity*	146 (88)	381 (79.4)	0.03
Low birthweight[†]	149 (89.8)	417 (86.9)	0.25
Sepsis	9 (5.4)	39 (8.1)	0.12
Perinatal Asphyxia	77 (46.4)	138 (28.8)	<0.001
HIE[‡]	28 (16.9)	56 (11.7)	0.09
Respiratory Distress Syndrome	12 (7.2)	23 (4.8)	0.15
Other	14 (8.4)	52 (10.8)	0.09
Unknown	0	7 (1.5)	0.12
Homebirth			
No	96 (57.8)	292 (60.8)	0.79
Yes	27 (16.3)	74 (15.4)	
Unknown	43 (25.9)	114 (23.8)	
Delivery Method			
Normal vaginal delivery	100 (60.2)	264 (55)	0.50
Caesarean Section	57 (34.3)	186 (38.8)	
Unknown	9 (5.4)	30 (6.3)	
Sharing an Incubator			
No	155 (93.4)	439 (91.5)	0.43
Yes	11 (6.6)	41 (8.5)	

*Prematurity, defined as birth before the completion of 37 weeks of pregnancy.

[†]Low birthweight, defined as a birthweight less than 2500g.

[‡]HIE, Hypoxic-Ischemic Encephalopathy

^{§§}P-value calculated using the Wilcoxon-Mann-Whitney test.

P-values were estimated using Wilcoxon-Mann-Whitney tests for medians and χ^2 test statistics for differences in proportions. Pearson's chi square test was the default test conducted.

Table 3: Crude and Adjusted Risk Odds Ratio Estimates and 95% Confidence Intervals (CI) for Neonatal Death within 48 hours of Admission to the SCANU, FMCH, Bangladesh, 2018

	Univariable Models		Multivariable Model	
	OR [¶]	95% CI ^{**}	aOR ^{††}	95% CI ^{**}
Age at admission (days)	0.93	0.88, 0.98	0.95	0.9, 0.99
Sex				
Female individuals	1	-	1	-
Male individuals	1.5	1.1, 2.2	1.5	1.04, 2.23
Admitting Diagnosis				
Prematurity*	2.2	1.2, 4.2	2.5	1.3, 4.7
Low birthweight[†]	1.2	0.7, 2.1	-	-
Sepsis	0.6	0.3, 1.3	-	-
Perinatal Asphyxia	2.1	1.5, 3.0	2.2	1.4, 3.4
HIE[‡]	1.5	0.9, 2.5	0.9	0.5, 1.6
Respiratory Distress Syndrome	1.5	0.7, 3.1	-	-
Homebirths				
No	1	-	-	-
Yes	1.1	0.7, 1.8	-	-
Delivery Method				
Normal vaginal delivery	1	-	-	-
Caesarean Section	0.8	0.6, 1.2	-	-
Sharing an Incubator				
No	1	-	-	-
Yes	0.8	0.4, 1.5	-	-

*Prematurity, defined as birth before the completion of 37 weeks of pregnancy.

[†]Low birthweight, defined as a birthweight less than 2500g.

[‡]HIE, Hypoxic-Ischemic Encephalopathy

[¶] ORs, Odds Ratios

^{**} CI, confidence intervals

^{††}aORs, adjusted Odds Ratios

P-values, ORs, aORs and CIs were estimated using the logistic regression models.

Figure 1: Conceptual Framework Outlining Potential Risk Factors Associated with Neonatal Death within the first 48 hours of Admission to the Special Care Newborn Unit (SCANU), Faridpur Medical College Hospital, 2018

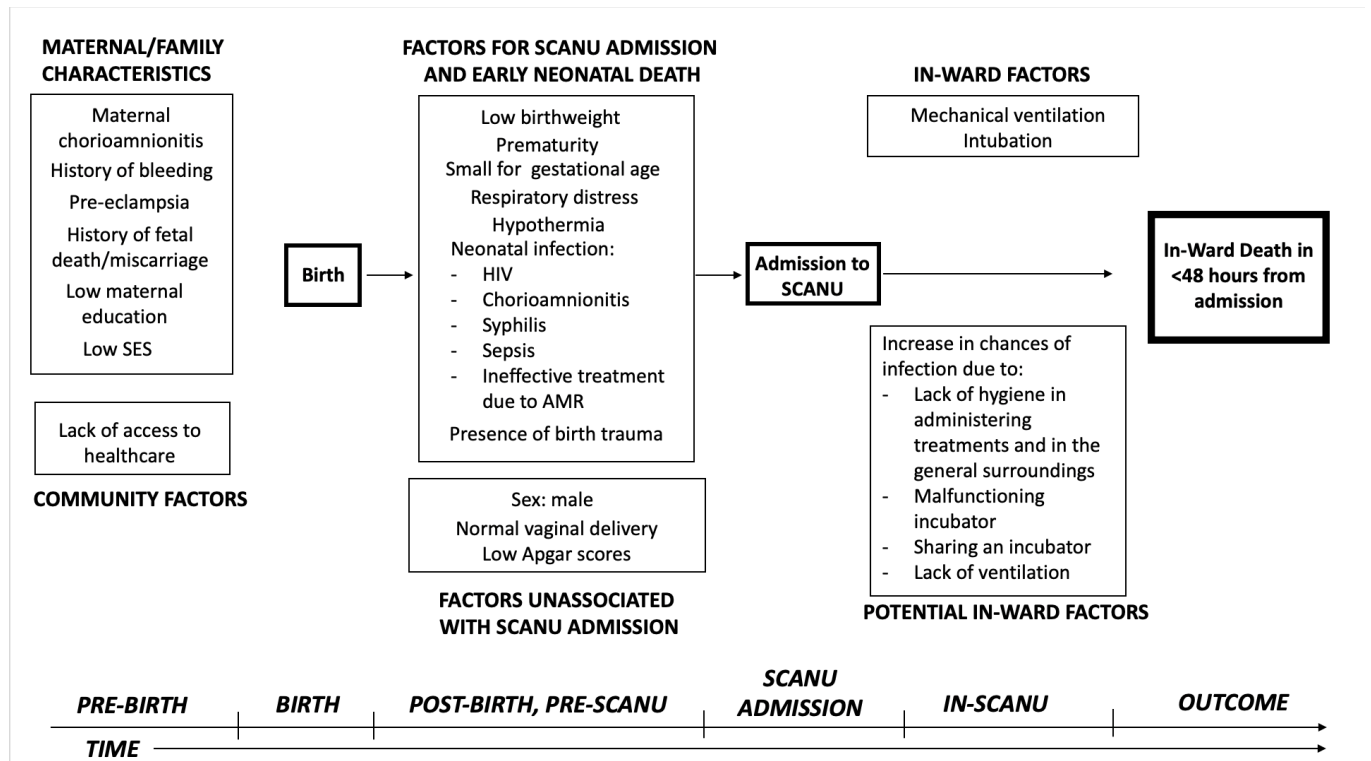


Figure 2

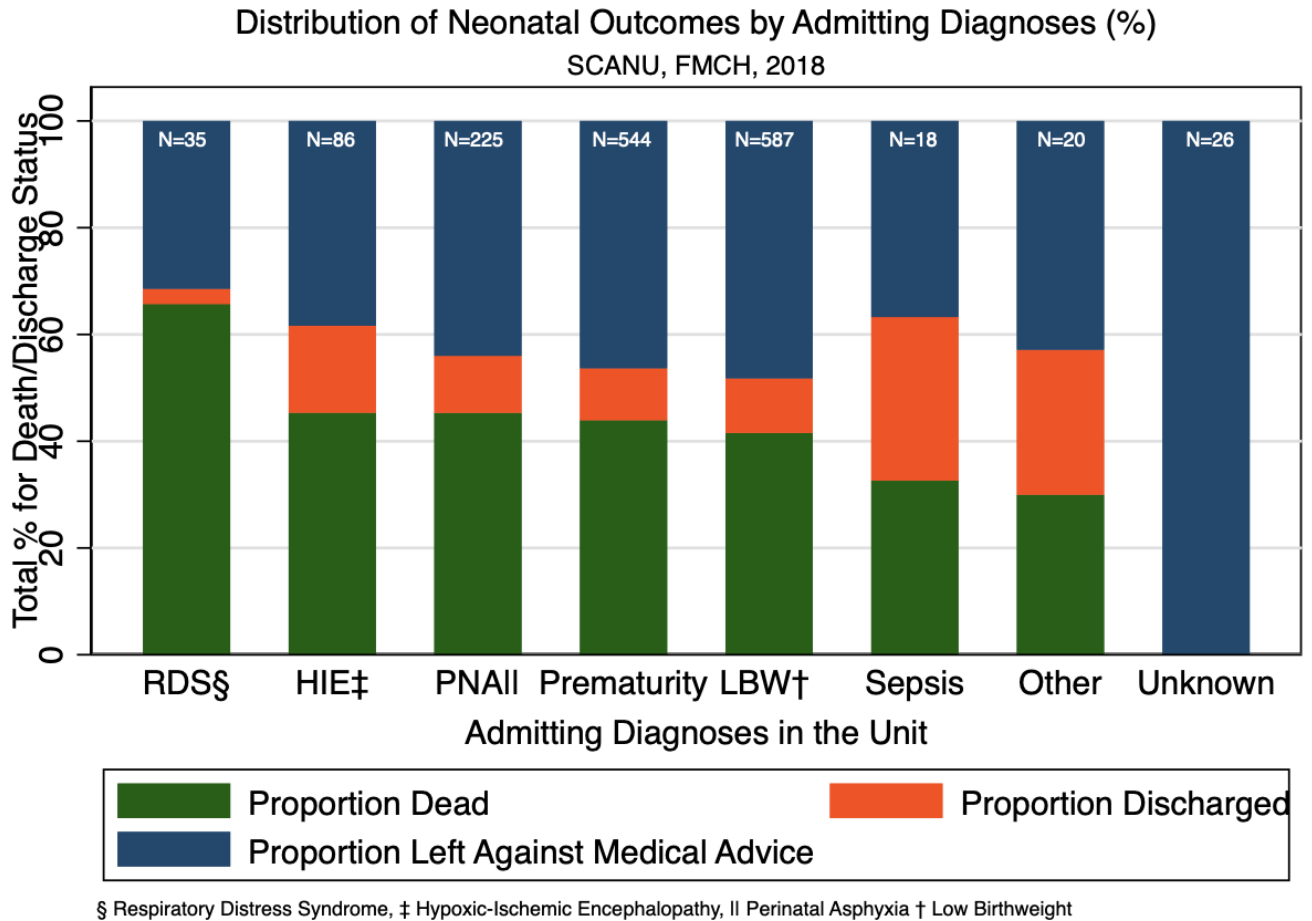


Figure 3

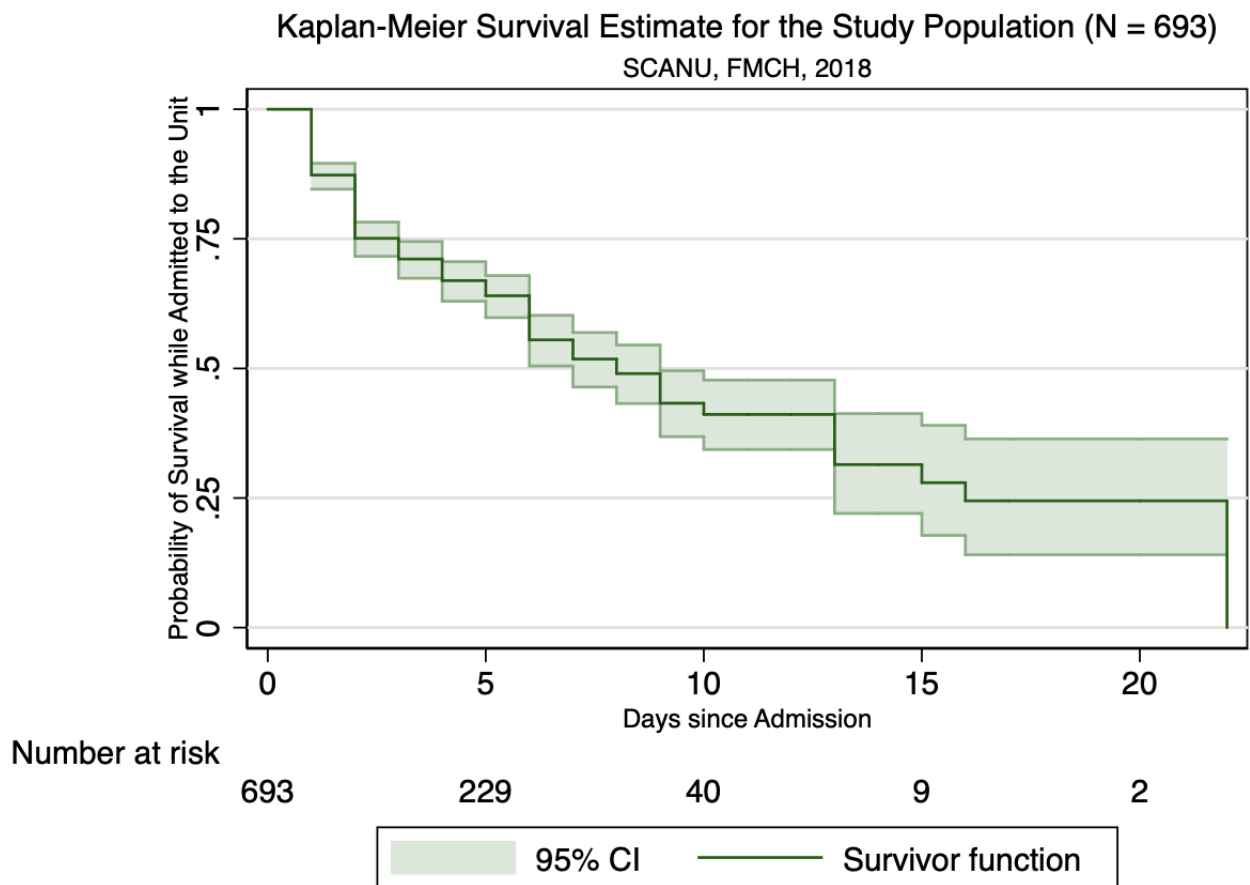
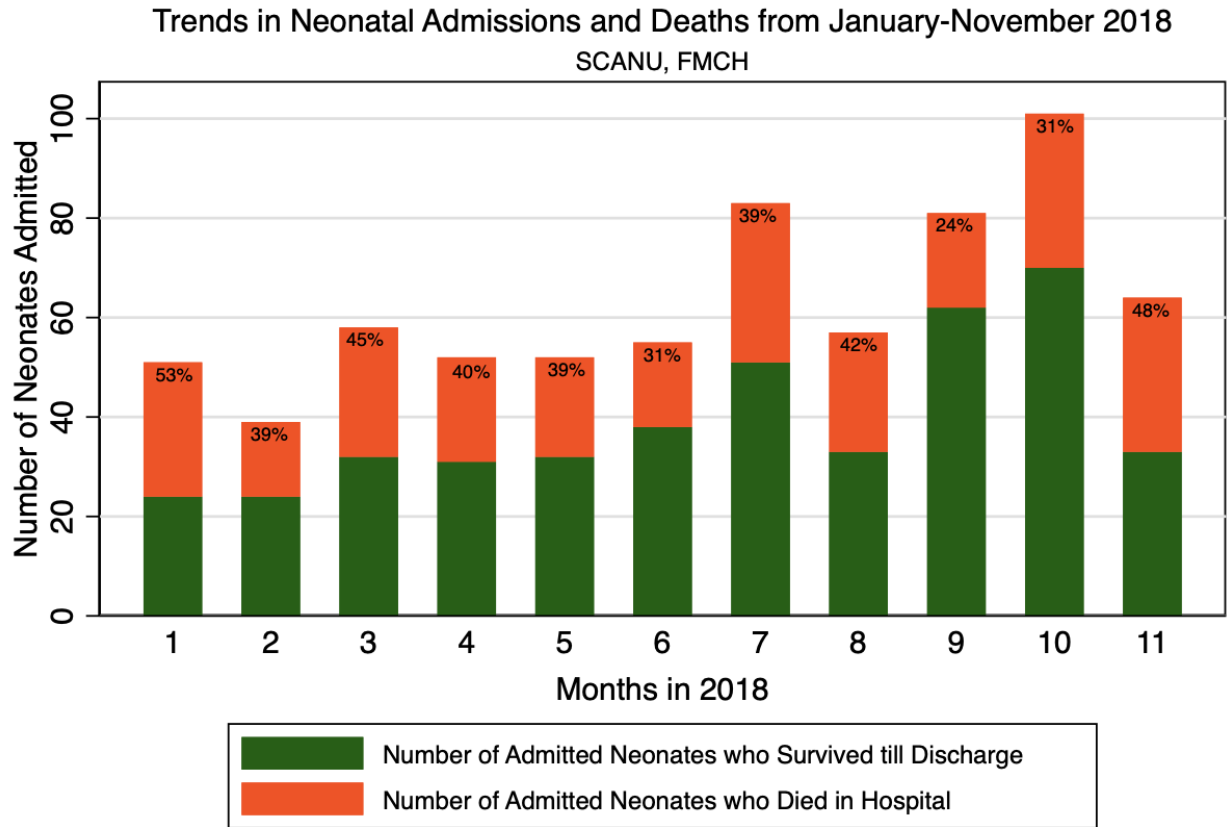


Figure 4



Percentages in the figure are the proportion of deaths occurring amongst those admitted each month.

Supplementary Appendices

Supplementary Table 1: Crude and Adjusted Risk Odds Ratio Estimates and 95% Confidence Intervals (CI) for Neonatal Death after Admission to the Unit (Outcome: 1 = Death, 0 = Survived)

	Univariable Models		Multivariable Model	
	OR [¶]	95% CI ^{**}	aOR ^{††}	95% CI ^{**}
Age at admission (days)	0.9	0.9, 0.97	0.95	0.9, 0.99
Sex				
Female individuals	1	-	1	-
Male individuals	1.2	0.9, 1.6	1.3	0.9, 1.8
Admitting Diagnosis				
Prematurity[*]	3.9	2.2, 6.8	3.9	1.8, 8.4
Low birthweight[†]	2.3	1.3, 3.9	1.4	0.6, 3.0
Sepsis	0.7	0.4, 1.3	0.46	0.25, 0.84
Perinatal Asphyxia	1.4	1.04, 2.0	1.6	1.1, 2.5
HIE[‡]	1.4	0.9, 2.2	-	-
Respiratory Distress Syndrome	3.1	1.5, 6.4	2.8	1.1, 6.8
Homebirths				
No	1	-	1	-
Yes	1.5	1.0, 2.3	1.7	1.1, 2.8
Delivery Method				
Normal vaginal delivery	1	-	-	-
Caesarean Section	0.8	0.6, 1.1	-	-
Sharing an Incubator				
No	1	-	-	-
Yes	1.3	0.76, 2.3	-	-

*Prematurity, defined as birth before the completion of 37 weeks of pregnancy.

[†]Low birthweight, defined as a birthweight less than 2500g.

[‡]HIE, Hypoxic-Ischemic Encephalopathy

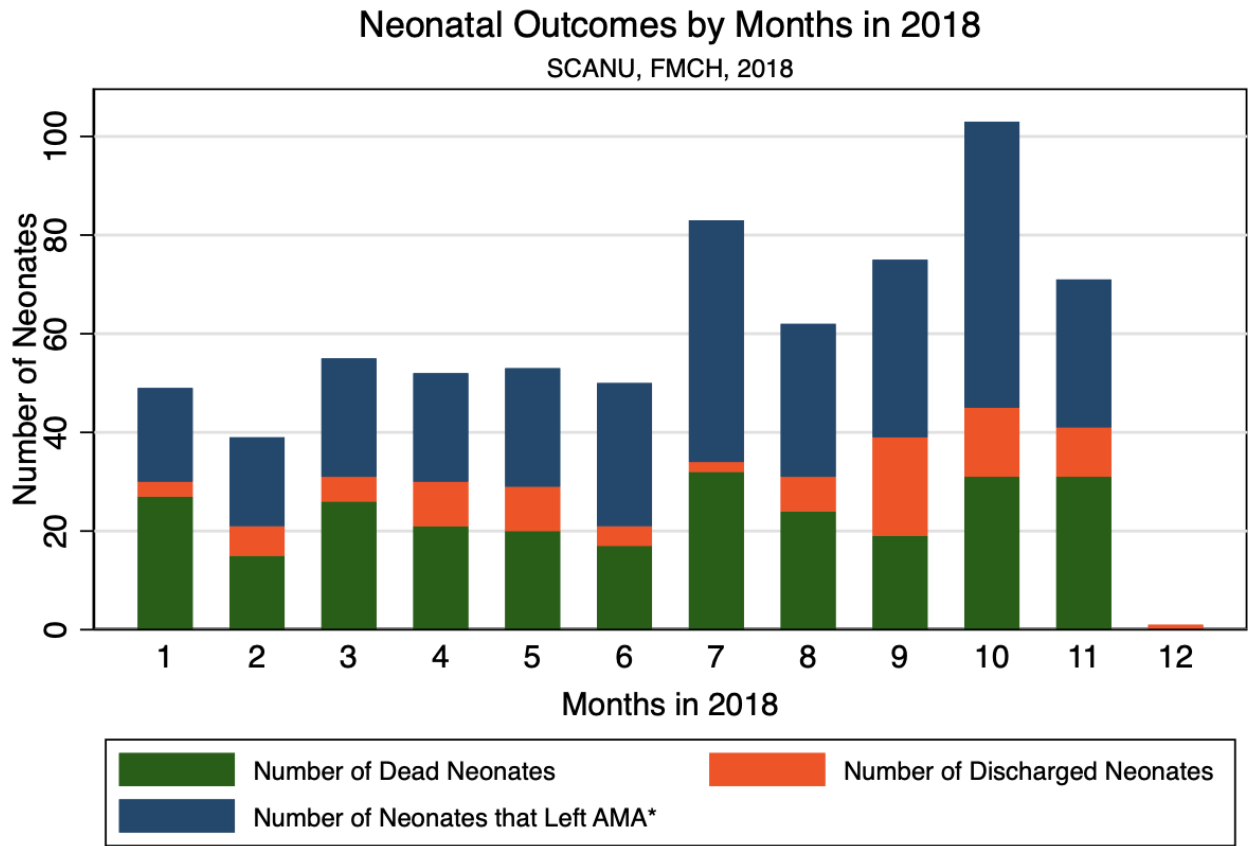
[¶] ORs, Odds Ratios

^{**} CI, confidence intervals

^{††} aORs, adjusted Odds Ratios

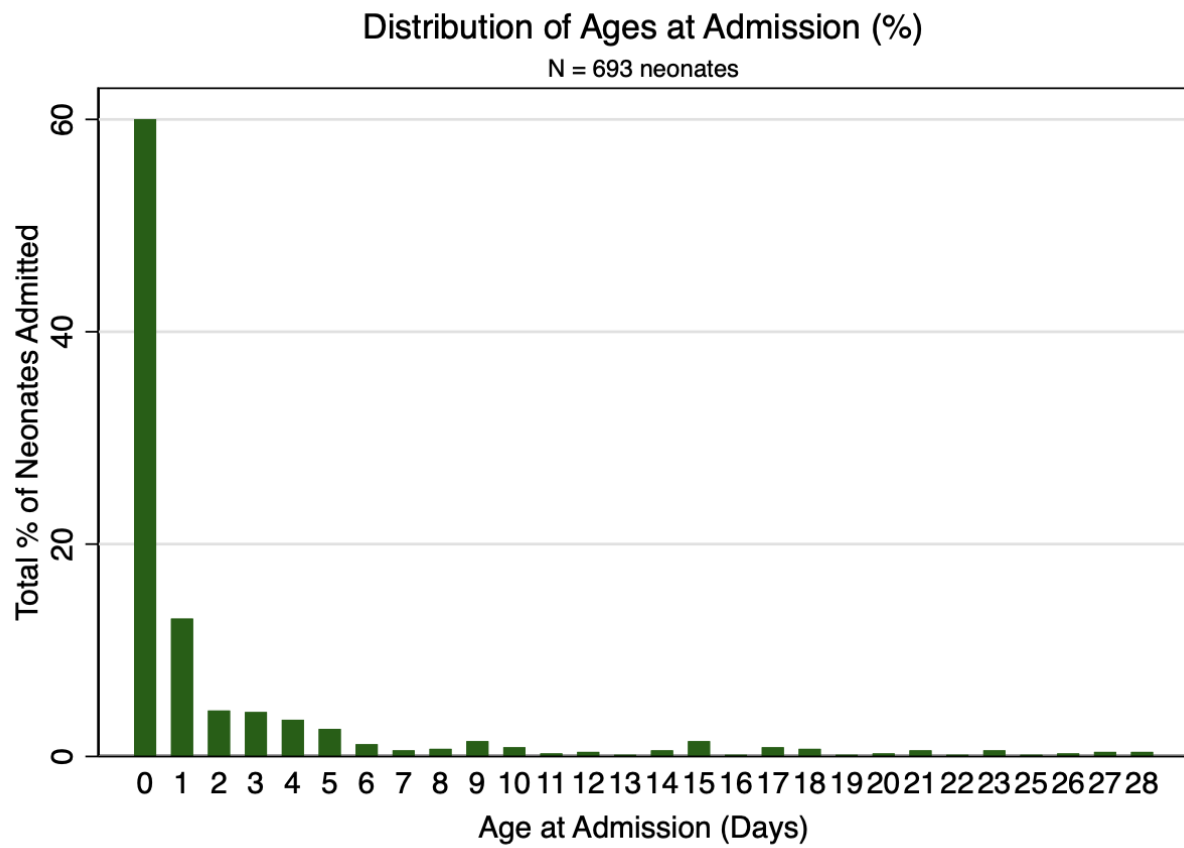
P-values, ORs, aORs and CIs were estimated using the logistic regression models.

Supplementary Figure 1: Outcomes by Month of Occurrence



*AMA = Against Medical Advice

Supplementary Figure 2: Admission to the Unit by Age at Admission in Days



Bibliography

1. Asian Development Bank. (2015). MDG 4: Reduce Child Mortality. (n.d.). *New Zealand*, 6.
2. Baqui, A. H., Rosen, H. E., Lee, A. C. C., Applegate, J. A., El Arifeen, S., Rahman, S. M., ... Black, R. E. (2013). Preterm birth and neonatal mortality in a rural Bangladeshi cohort: implications for health programs. *Journal of Perinatology*, 33(12), 977–981. <https://doi.org/10.1038/jp.2013.91>
3. Becker, S., Weng, S. (1998). Seasonal patterns of deaths in Matlab, Bangladesh. *International Journal of Epidemiology*, 27, 814-823. <https://doi-org.proxy1.library.jhu.edu/10.1093/ije/27.5.814>
4. Bhutta, Z. (1997). Profile and outcome of the respiratory distress syndrome among newborns in Karachi: risk factors for mortality. *Journal of Tropical Pediatrics*, 43(3), 143–148. <https://doi.org/10.1093/tropej/43.3.143>
5. Central Intelligence Agency (2019, April). South Asia: Bangladesh. *The World Factbook*. Retrieved from <https://www.cia.gov/library/publications/the-world-factbook/geos/bg.html>
6. Chowdhury, H. R., Thompson, S., Ali, M., Alam, N., Yunus, M., & Streatfield, P. K. (2010). Causes of Neonatal Deaths in a Rural Subdistrict of Bangladesh: Implications for Intervention. *Journal of Health, Population and Nutrition*, 28(4), 375–382. <https://doi.org/10.3329/jhpn.v28i4.6044>
7. Directorate General of Health Services. (2011, November). Standard Operating Procedure (SOP) For Newborn Care Services at Primary and Secondary Level Hospitals.

Retrieved from

http://www.dghs.gov.bd/licts_file/images/SOP/2011_Newborn_Care_SOP_29-11-11.pdf

8. Directorate General of Health Services. (2017, April) National Newborn Health Bulletin Issue 2. Retrieved from <https://www.healthynewbornnetwork.org/resource/bangladesh-newborn-bulletin/>
9. Grünebaum, A., McCullough, L. B., Arabin, B., Dudenhausen, J., Orosz, B., & Chervenak, F. A. (2017). Underlying causes of neonatal deaths in term singleton pregnancies: home births versus hospital births in the United States. *Journal of Perinatal Medicine*, 45(3). <https://doi.org/10.1515/jpm-2016-0200>
10. Halim A., Dewez JE, Biswas A, Rahman F, White S, et al. (2016) When, Where, and Why Are Babies Dying? Neonatal Death Surveillance and Review in Bangladesh. *PLOS ONE*, 11(8): e0159388. <https://doi.org/10.1371/journal.pone.0159388>
11. Hermansen, C. L., & Lorah, K. N. (2007). Respiratory Distress in the Newborn. *American Family Physician*, 76(7), 987-994.
12. International Development Research Centre (2018, January). Making healthcare accessible in Bangladesh. Retrieved from <https://www.idrc.ca/en/research-in-action/making-healthcare-accessible-bangladesh>
13. Kamal, S. M. M. (2015). What Is the Association Between Maternal Age and Neonatal Mortality? An Analysis of the 2007 Bangladesh Demographic and Health Survey. *Asia Pacific Journal of Public Health*, 27(2), NP1106–NP1117. <https://doi.org/10.1177/1010539511428949>

14. Kamal, S. M. M., Ashrafuzzaman, M., & Nasreen, S. A. (2012). Risk Factors of Neonatal Mortality in Bangladesh. *Journal of Nepal Paediatric Society*, 32(1), 37–46.
<https://doi.org/10.3126/jnps.v32i1.4845>
15. Kent, A. L., Wright, I. M. R., Abdel-Latif, M. E., & the New South Wales and Australian Capital Territory Neonatal Intensive Care Units Audit Group. (2012). Mortality and Adverse Neurologic Outcomes Are Greater in Preterm Male Infants. *PEDIATRICS*, 129(1), 124–131. <https://doi.org/10.1542/peds.2011-1578>
16. Khatun, F., Rasheed, S., Moran, A. C., Alam, A. M., Shomik, M. S., Sultana, M., ... Bhuiya, A. (2012). Causes of neonatal and maternal deaths in Dhaka slums: Implications for service delivery. *BMC Public Health*, 12(1). <https://doi.org/10.1186/1471-2458-12-84>
17. Lawn, J. E., Cousens, S., & Zupan, J. (2005). 4 million neonatal deaths: When? Where? Why? *The Lancet*, 365(9462), 891–900. [https://doi.org/10.1016/S0140-6736\(05\)71048-5](https://doi.org/10.1016/S0140-6736(05)71048-5)
18. Liu, L., Johnson, H. L., Cousens, S., Perin, J., Scott, S., Lawn, J. E., ... Black, R. E. (2012). Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000. *The Lancet*, 379(9832), 2151–2161.
[https://doi.org/10.1016/S0140-6736\(12\)60560-1](https://doi.org/10.1016/S0140-6736(12)60560-1)
19. Mickey, R. M., & Greenland, S. (1989). THE IMPACT OF CONFOUNDER SELECTION CRITERIA ON EFFECT ESTIMATION. *American Journal of Epidemiology*, 129(1), 125–137. <https://doi.org/10.1093/oxfordjournals.aje.a115101>
20. Mitra, D. K., Mullany, L. C., Harrison, M., Mannan, I., Shah, R., ... Baqui, A. H. (2018). Incidence and risk factors of neonatal infections in a rural Bangladeshi population: a community-based prospective study. *Journal of Health, Population and Nutrition*, 37(1).
<https://doi.org/10.1186/s41043-018-0136-2>

21. Naeye R. L., Burt L. S., Wright D. L., Blanc W. A., Tatter D. (1971) Neonatal mortality, the male disadvantage. *PEDIATRICS*, 48: 902–6.
22. Neogi, S. B., Malhotra, S., Zodpey, S., & Mohan, P. (2011). Assessment of special care newborn units in India. *Journal of Health, Population, and Nutrition*, 29(5), 500-9.
23. Owais A, Faruque ASG, Das SK, Ahmed S, Rahman S, et al. (2013). Maternal and Antenatal Risk Factors for Stillbirths and Neonatal Mortality in Rural Bangladesh: A Case-Control Study. *PLoS ONE* 8(11): e80164.
<https://doi.org/10.1371/journal.pone.0080164>
24. Roy, S., & Haque, M. A. (2018). Effect of antenatal care and social well-being on early neonatal mortality in Bangladesh. *BMC Pregnancy and Childbirth*, 18(1).
<https://doi.org/10.1186/s12884-018-2129-y>
25. Sankar, M. J., Natarajan, C. K., Das, R. R., Agarwal, R., Chandrasekaran, A., & Paul, V. K. (2016). When do newborns die? A systematic review of timing of overall and cause-specific neonatal deaths in developing countries. *Journal of Perinatology*, 36(S1), S1–S11. <https://doi.org/10.1038/jsp.2016.27>
26. Save the Children, Bangladesh. (2016, October). Lakshmipur Gets Its First Special Care Unit for Newborns. Retrieved from
<https://bangladesh.savethechildren.net/news/lakshmipur-gets-its-first-special-care-unit-newborns>
27. Shah, R., Mullany, L. C., Darmstadt, G. L., Talukder, R. R., Rahman, S. M., Mannan, I., Arifeen, S. E., Baqui, A. H. (2014). Neonatal mortality, preterm birth, mortality risk, Bangladesh. *Paediatr Perinat Epidemiol*, 28: 510-520. <https://doi.org/10.1111/ppe.12145>

28. U.S. Agency for International Development. (2019, March). Saving Newborn Lives in Bangladesh. Retrieved from www.usaid.gov/news-information/photo-gallery/saving-newborn-lives-bangladesh.
29. UNICEF Bangladesh. Saving Newborn Lives. Retrieved from www.unicef.org/bangladesh/en/saving-newborn-lives.
30. UNICEF Data. (2018, March). Neonatal mortality. Retrieved from <https://data.unicef.org/topic/child-survival/neonatal-mortality/>
31. UN Inter-agency Group for Child Mortality Estimation. (2018). Levels and Trends in Child Mortality. Retrieved from https://childmortality.org/files_v22/download/UN%20IGME%20Child%20Mortality%20Report%202018.pdf
32. United Nations. (2013). The Millennium Development Goals Report. Retrieved from [http://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20\(July%201\).pdf](http://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf)
33. United Nations. (2015). Millennium Development Goals and Beyond. Retrieved from <http://www.un.org/millenniumgoals/childhealth.shtml>
34. United Nations. (2018). Sustainable Development Goal 3. Retrieved from <https://sustainabledevelopment.un.org/sdg3>
35. United Nations Development Programme. (2015). Millennium Development Goal 4. Retrieved from https://www.undp.org/content/undp/en/home/sdgooverview/mdg_goals/mdg4.html

36. United Nations Development Programme, Bangladesh. Millennium Development Goal 4.
Retrieved from <http://www.bd.undp.org/content/bangladesh/en/home/post-2015/millennium-development-goals/mdg4.html>
37. Tagare, A., Chaudhari, S., Kadam, S., Vaidya, U., Pandit, A., & Sayyad, M. G. (2013).
Mortality and Morbidity in Extremely Low Birth Weight (ELBW) Infants in a Neonatal
Intensive Care Unit. *The Indian Journal of Pediatrics*, 80(1), 16–20.
<https://doi.org/10.1007/s12098-012-0818-5>
38. Zupan, J., & Åhman, E. (2006). *Neonatal and perinatal mortality: country, regional and global estimates*. Geneva: World Health Organization.

Biography

Ananya Kumar was born in 1995, in Chennai, India. She graduated magna cum laude from St. Xavier's College, Mumbai with a Bachelor of Science in microbiology and biochemistry in 2016 and went on to work as a project research intern in a neurobiology laboratory at the Indian Institute of Science Education and Research, Pune.

In 2017, Ananya began her graduate studies at the Johns Hopkins Bloomberg School of Public Health and is currently pursuing a Master of Science degree in Epidemiology, with a focus on infectious diseases. She plans to graduate in May 2019. While at Johns Hopkins, Ananya worked with the cholera dynamics group as well as the International Vaccine Access Center and served as a teaching assistant for introductory epidemiology and outbreak investigation courses.